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COMPACTION CHARACTERISTICS OF EARTH-ROCK MIXTURES

REPORT 1. VICKSBURG SILTY CLAY AND DEGRA'
DAM CLAYEY SANDY GRAVEL

ARMY ENGINEER WATERWAYS EXPERIMENT STATION
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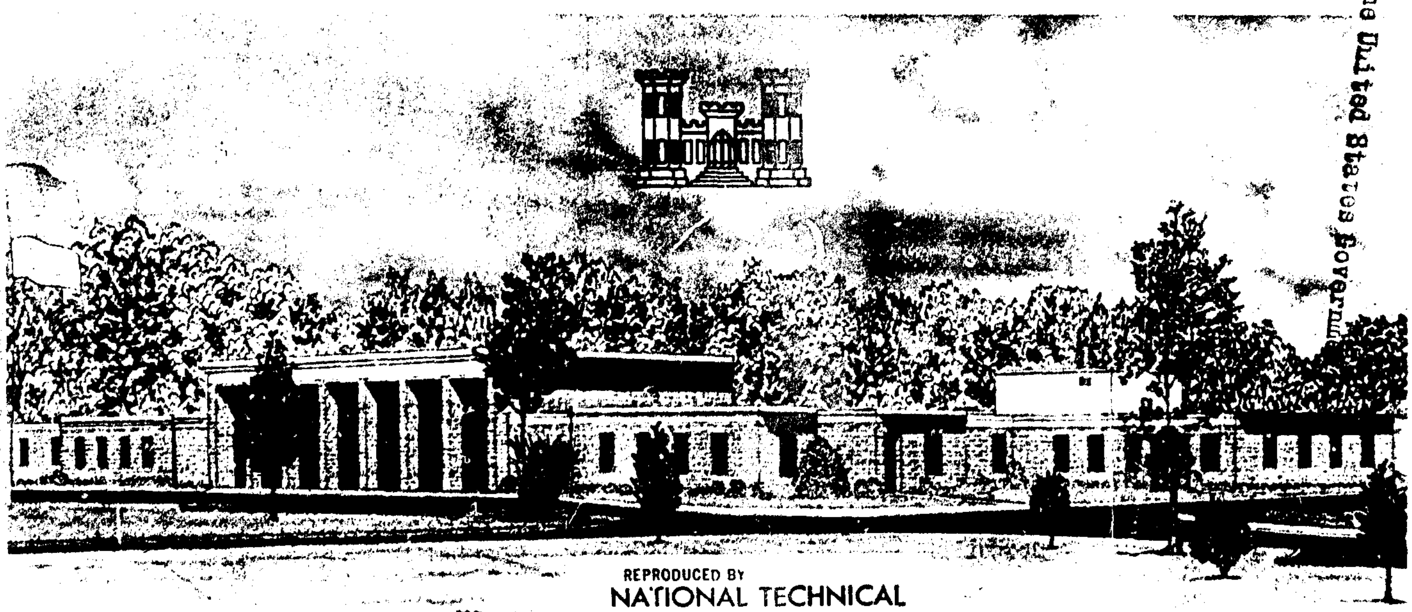
COMPACTION CHARACTERISTICS OF EARTH-ROCK MIXTURES

Report 1

VICKSBURG SILTY CLAY AND DEGRAY DAM CLAYEY SANDY GRAVEL

by

R. T. Donaghe, F. C. Townsend



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13. ABSTRACT Due to limitations of equipment size, compaction characteristics of earth-rock materials are usually determined by laboratory tests of samples contained in small molds and having maximum particle diameters less than those of the in situ soil. Corps of Engineers' laboratories perform such tests on samples from which oversized particles have been scalped and replaced, assuming that test results are comparable to those that would have been obtained on full-scale samples. The purpose of this investigation was to determine effects on compaction characteristics of earth-rock mixtures due to the size of compaction equipment used and the altered gradation resulting from the scalping and replacement procedure. A mechanical compactor equipped with 18-, 12-, and 6-in.-diam molds and 5.5- and 24.7-lb rammers having diameters of 2.0 and 6.0 in., respectively, was utilized for the testing. Comparative tests were performed with a hand-held hammer utilizing standard procedures. Materials tested were Vicksburg silty clay (CL) having LL = 43 and PL = 22 and a clayey sandy gravel (GC) (LL = 37 and PL = 14) with maximum particle size of approximately 3 in. from DeGray Dam in Arkansas. Samples of the CL material were batched using either a commercial kitchen mixer or a pugmill. All of the CL specimens were compacted in three layers using compactive efforts approximately equal to the standard effort (12,300 ft-lb/ft^3) by adjusting the number of blows. A total of seven compaction curves were developed for the Vicksburg silty clay (CL) and six compaction curves were developed for the clayey sandy gravel. Results of tests performed on the CL material indicate that mold diameters may be varied from 6 to 18 in. without significant effects on maximum dry unit weight and optimum water content. Results of tests on the CL material also show that compaction characteristics are not significantly affected by pugmill versus mixer processing. Results of tests performed on clayey sandy gravel show that significant differences in maximum dry unit weight and optimum water content are obtained in tests performed on samples having a maximum particle size of 3 in. using an 18-in.-diam mold and tests on samples having a maximum particle size of 3/4 in. with replacement of plus 3/4-in. material performed in a 6-in.-diam mold. The maximum dry unit weight was decreased from 127.9 lb per cu ft on the total sample to 123.6 lb per cu ft, and the optimum water content was increased from 8.7 to 10.3 percent. Tests on both materials (CL and GC) indicated that the mechanical compactor consistently gave higher maximum dry unit weights and somewhat lower optimum water contents than the conventional hand-held, sliding-weight rammer. Further testing is required to fully define the effects of scalping and replacing coarse material on the compaction characteristics of earth-rock mixtures.

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FOREWORD

This investigation is part of a study to determine compaction characteristics of earth-rock mixtures: Engineering Study (ES) 543, entitled "Shear Strengths of Earth-Rock Mixtures." Authorization for the testing program was given by the Office, Chief of Engineers (OCE), 1st Ind dated 30 May 1972 to U. S. Army Engineer Waterways Experiment Station (WES) letter (WESSE) dated 18 May 1972, subject: Compaction Testing Program, ES 543. The testing was performed during the period May through August 1972.

The study was conducted by Messrs. R. T. Donaghe and W. J. Hughes, Laboratory Research Section, Embankment and Foundation Branch, Soils and Pavements Laboratory, under the supervision of Dr. F. C. Townsend, Chief, Laboratory Research Section, and the general direction of Mr. J. R. Compton, Chief, Embankment and Foundation Branch, and Messrs. J. P. Sale and R. G. Ahlvin, Chief and Assistant Chief, respectively, Soils and Pavements Laboratory. The report was prepared by Mr. Donaghe and Dr. Townsend.

COL Ernest D. Peixotto, CE, was Director of WES during preparation of this report. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.0185	kilograms per cubic meter
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters

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SUMMARY

Due to limitations of equipment size, compaction characteristics of earth-rock materials are usually determined by laboratory tests on samples contained in small molds and having maximum particle diameters less than those of the in situ soil. Corps of Engineers' laboratories perform such tests on samples from which oversized particles have been scalped and replaced, assuming that test results are comparable to those that would have been obtained on full-scale samples. The purpose of this investigation was to determine effects on compaction characteristics of earth-rock mixtures due to the size of compaction equipment used and the altered gradation resulting from the scalping and replacement procedure.

A mechanical compactor equipped with 18-, 12-, and 6-in.-diam molds and 5.5- and 24.7-lb rammers having diameters of 2.0 and 6.0 in., respectively, was utilized for the testing. Comparative tests were performed with a hand-held hammer utilizing standard procedures. Materials tested were Vicksburg silty clay (CL) having LL = 43 and PL = 22 and a clayey sandy gravel (GC) (LL = 37 and PL = 14) with maximum particle size of approximately 3 in. from DeGray Dam in Arkansas. Samples of the CL material were batched using either a commercial kitchen mixer or a pugmill. All of the specimens were compacted in three layers using compactive efforts approximately equal to the standard effort (12,300 ft-lb/ft^3) by adjusting the number of blows.

A total of seven compaction curves were developed for the Vicksburg silty clay (CL) and six compaction curves were developed for the clayey sandy gravel. Results of tests performed on the CL material indicate that mold diameters may be varied from 6 to 18 in.

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without significant effects on maximum dry unit weight and optimum water content. Results of tests on the CL material also show that compaction characteristics are not significantly affected by pugmill versus mixer processing. Results of tests performed on clayey sandy gravel show that significant differences in maximum dry unit weight and optimum water content are obtained in tests performed on samples having a maximum particle size of 3 in. using an 18-in.-diam mold and tests on samples having a maximum particle size of 3/4 in. with replacement of plus 3/4-in. material performed in a 6-in.-diam mold. The maximum dry unit weight was decreased from 127.9 lb per cu ft on the total sample to 123.6 lb per cu ft, and the optimum water content was increased from 8.7 to 10.3 percent. Tests on both materials (CL and GC) indicated that the mechanical compactor consistently gave higher maximum dry unit weights and somewhat lower optimum water contents than the conventional hand-held, sliding-weight rammer. Further testing is required to fully define the effects of scalping and replacing coarse material on the compaction characteristics of earth-rock mixtures.

COMPACTION CHARACTERISTICS OF EARTH-ROCK MIXTURES

Report 1

VICKSBURG SILTY CLAY

AND DEGRAY DAM CLAYEY SANDY GRAVEL

Introduction

1. Laboratory tests to determine compaction characteristics of earth-rock mixtures for use in field control have been subject to question for many years. Due to limitations of equipment size, laboratory tests are generally performed on small samples, thus placing a limit on the maximum diameter of the particles contained in the samples. Many laboratories, including those of the Corps of Engineers, scalp oversized particles of in situ soils and replace the particles with an equal percentage by weight of smaller particles, assuming that results from tests performed in small molds on such material are comparable to those obtained from tests performed on full-scale samples in large molds.* Other laboratories perform compaction tests on the minus No. 4 fraction of soils in small molds and then apply theoretical correction factors based on the influence of gravel on compaction characteristics to compute densities of the in situ soils containing gravel. In both cases, however, various investigators have found that additional modifications have to be made to the small-sample test results in order to get agreement with the results of tests of full-size samples.[1,2,3]

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* The scalping and replacement procedure used in Corps of Engineers Division Laboratories for total samples having particles larger than 3/4 in. and finer than 2 in. is given in the appendix of this report. A table of factors for converting British units of measurement to metric units is presented on page ix.

2. The scalping and replacement procedure used in Corps of Engineers Division Laboratories results in samples with the same gravel content but with an altered gradation. Cunny and Strohm[4] have shown that for tests performed using this procedure on a clayey gravel (GC) containing 3-in.-diam particles and 36 percent passing the No. 200 sieve (LL = 31, PI = 11), densities obtained on minus 3/4-in.-diam material with replacement were about 0.5 pcf higher than those obtained on the total sample. The results of their investigation indicate that tests performed on scalped and replaced material having a 3/4-in. maximum particle size are comparable to those for the full-scale material and that effects due to the altered gradations are insignificant. Conversely, Holtz and Lowitz[5] have shown that for tests performed using the same procedure on a clayey gravel (GC) containing 3-in.-diam particles and 30 percent passing the No. 200 sieve (LL = 49, PI = 28), densities obtained on minus 3/4-in. material with replacement were approximately 4 pcf less than those obtained on the total sample, thus indicating that the altered gradation may significantly affect test results. Tests performed by the South Atlantic Division Laboratory[6] using the same procedure on a clayey gravel (GC) also showed a significant difference in the density obtained on a total sample and that for scalped and replaced material. Their investigation showed that the density obtained for a minus 3/4-in. material with replacement was about 6 pcf less than that obtained for a total sample containing 2-in.-diam particles with 14 percent passing the No. 200 sieve (LL = 42, PI = 11). Tests performed by several investigators appear to show that the magnitude of the difference in density obtained for the total sample and for the scalped and replaced material is a function of the percentage of material scalped and the resulting alteration in gradation.[1,3,6]

3. An additional consideration that may account for a portion of the difference in densities obtained for total samples and for scalped and replaced materials tested in small molds may be the size of the mold and compaction equipment used. The U. S. Bureau of Reclamation[3] has shown that when scalped and replaced material used for tests performed in 4.3-in.-diam molds was tested in 19.3-in.-diam molds, the resulting density was as much as 9 pcf higher than that determined using the smaller mold. It should be noted, however, that this difference resulted when a 185.7-lb hammer was used with the larger mold and a 5.5-lb hammer was used with the small mold. Ziegler,[1] Cunny and Strohm,[4] and the South Atlantic Division Laboratory[6] have, on the other hand, indicated that the variation in densities determined using various sizes of molds was limited to not more than 4 pcf and usually less than 2 pcf. In these investigations the maximum hammer weight was 11.5 lb.[6]

Objectives

4. The objectives of this investigation were:

a. To determine the equipment effects of large molds and hammers utilized for compaction of earth-rock mixtures by developing compaction curves for a cohesive soil containing no gravel.

b. To determine the effects of scalping and replacement of oversize particles on the compaction characteristics of earth-rock mixtures when smaller molds are used.

Equipment

5. A mechanical compactor manufactured by Howard Company and on loan from the Albuquerque District was utilized for the testing. The mechanical compactor is equipped with 18-, 12-, and 6-in.-diam molds and 5.5- and 24.7-lb rammers having diameters of 2.0 and 6.0 in., respectively. A special harness rigged with an electronic load cell sensitive to within 0.1 lb was used to obtain the specimen-plus-mold weights for tests performed with the 12- and 18-in.-diam molds. A photograph of the compactor, the 12- and 18-in.-diam molds, and the weighing harness is shown in fig. 1. All other weights were obtained with a scale having a sensitivity of 0.01 lb. Calibration data for the molds furnished with the mechanical compactor are as follows:

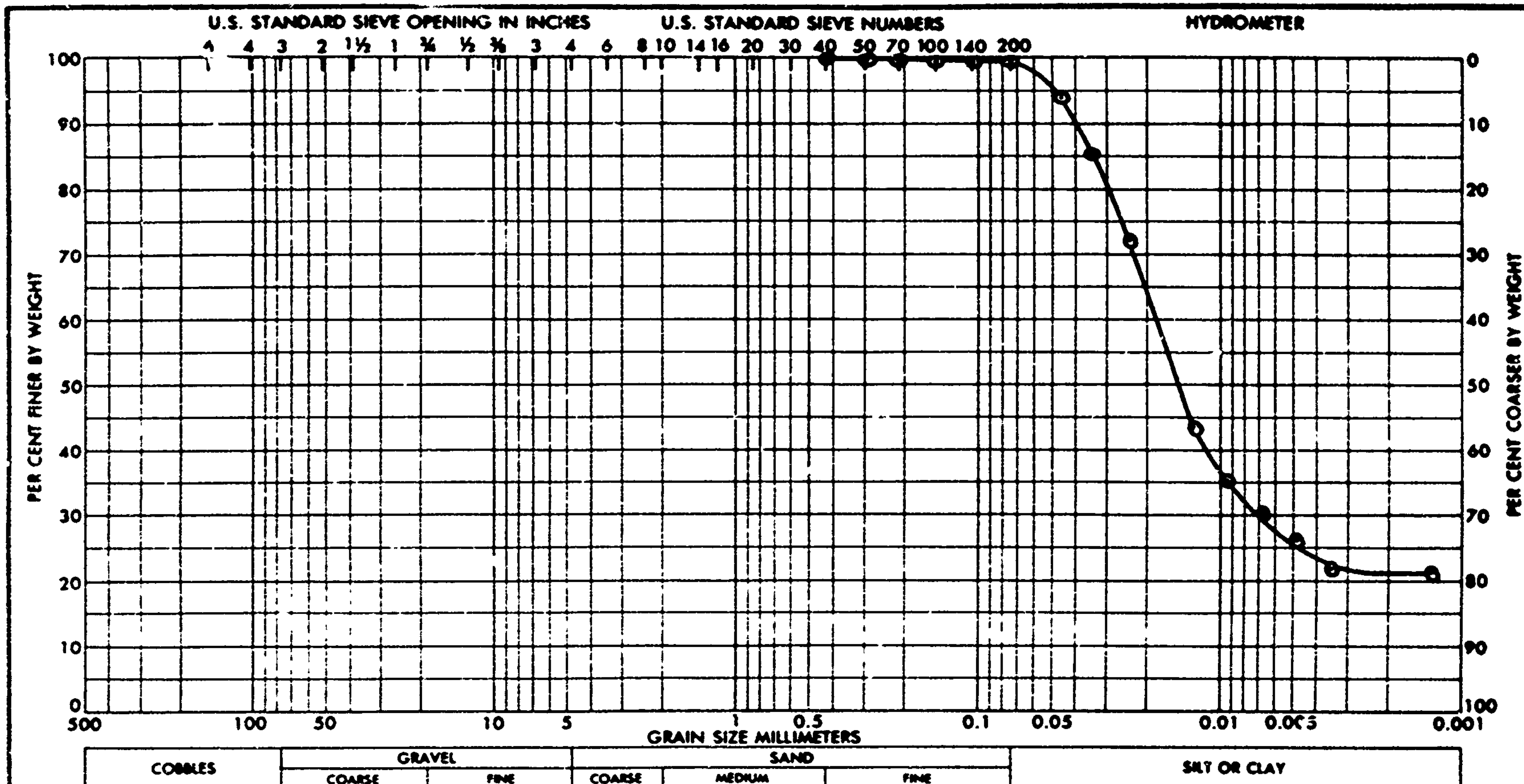
Nominal Mold ID, in.	Area ft^2	Height in.	Volume ft^3	Weight lb
6	0.196	4.582	0.075	6.21
12	0.785	12.013	0.786	141.1
18	1.767	18.005	2.651	321.4

Equipment used for comparative tests with the hand-held hammer conformed to that described in the laboratory soils testing manual, EM 1110-2-1906.[7]

Materials

6. The cohesive soil containing no gravel used in the testing program was Vicksburg silty clay (CL) having LL = 43 and PL = 22. Gradation of the material is presented in fig. 2. The earth-rock mixture was obtained from borrow area "F" at DeGray Dam in Arkansas and is characterized as a clayey sandy gravel with maximum particle

Fig. 1. Howard mechanical compactor with 12- and 18-in.-diam molds and load cell harness for weighing



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	PROJECT VICKSBURG SILTY CLAY
		CLAY (CL)		43	22	21	

Fig. 2. Grain-size distribution curve and classification data, Vicksburg siliy clay (CL)

sizes of about 3 in.; the minus No. 40 fraction had Atterberg limits of LL = 37 and PL = 14. Gradation curves for the DeGray material are given in fig. 3. Prior to use in the compaction program, both materials were dried on a heated floor. The CL material was passed through a hammer mill to break down aggregations of dried soil The DeGray material was screened into appropriate fractions: plus 3-in. diameter, 3 to 2 in., 2 to 1-1/2 in., 1-1/2 to 1 in., 1 to 3/4 in., 3/4 to 1/2 in., 1/2 to 3/8 in., 3/8 to plus No. 4, and minus No. 4. The plus No. 4 material was washed in order to remove fines adhering to the larger particles. Figs. 4 through 7 are photographs of the various fractions of the DeGray material.

Procedure

7. Maximum particle sizes used in testing the DeGray material were 3 in. for the 18-in.-diam mold, 2 in. for the 12-in.-diam mold, 3/4 in. for the 6-in.-diam mold, and No. 4 sieve size for the 4-in.-diam mold. Oversized particles were replaced with an equal percentage of smaller gravel-sized material so that the gradation of the minus No. 4 fraction was unchanged. Grain-size distribution curves for these materials are shown in fig. 3.

8. Batches for test specimens of CL material were prepared by adding the desired weight of water to a sufficient quantity of air-dry soil and mixing in either a commercial kitchen mixer or a pugmill. Since the mixer was limited in the amount of material that could be prepared in an individual batch, the pugmill generally was used to prepare the larger batches required for the 12- and 18-in.-diam molds. However, in order to determine possible effects on compaction characteristics due to the two batching procedures, one

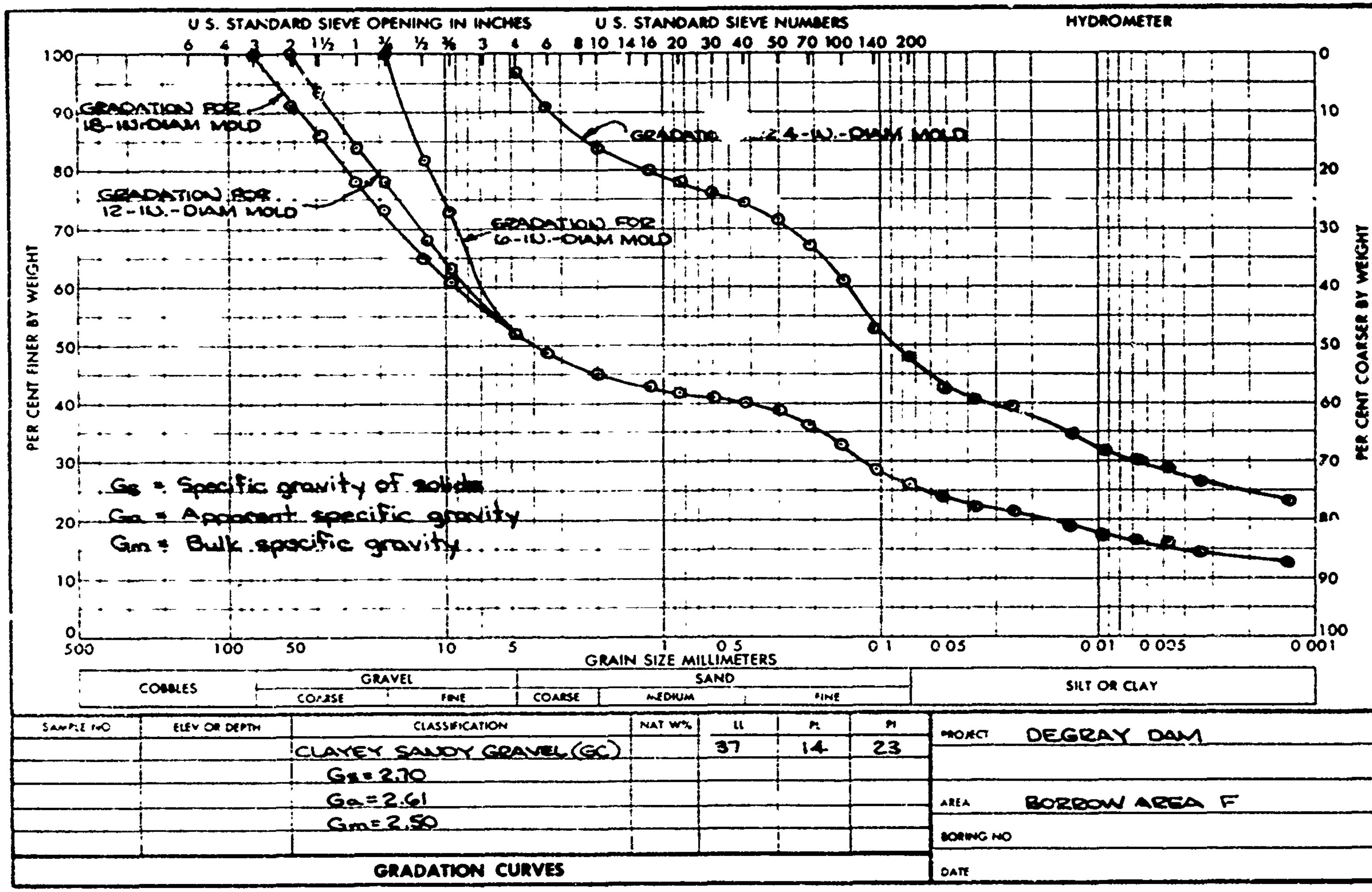
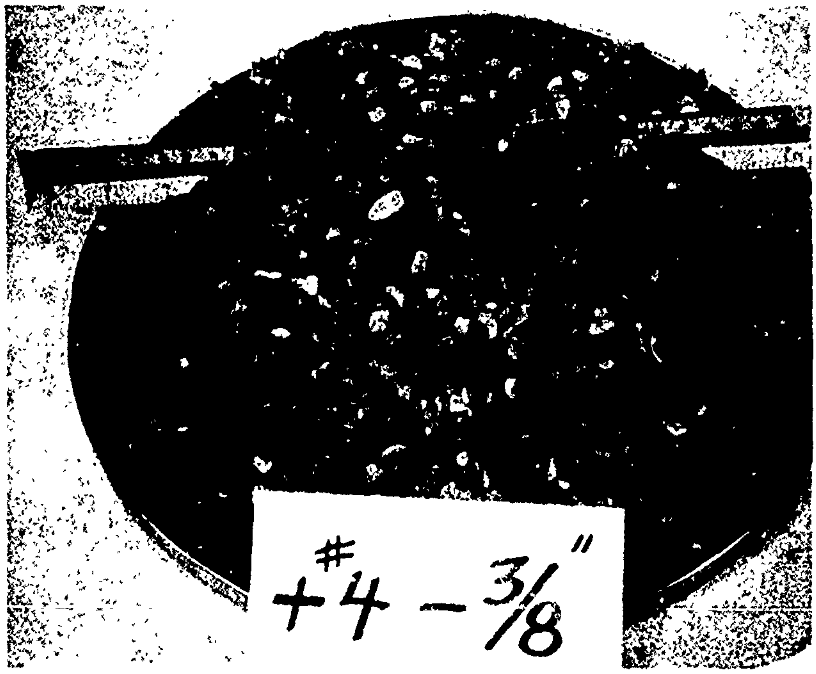
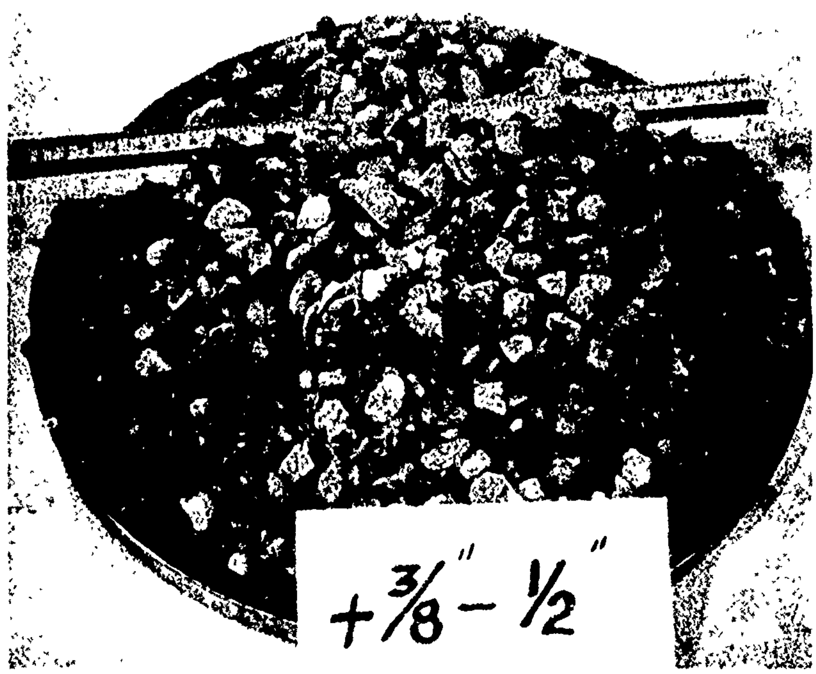


Fig. 3. Grain-size distribution curves and classification data, clayey sandy gravel from DeGray Dam

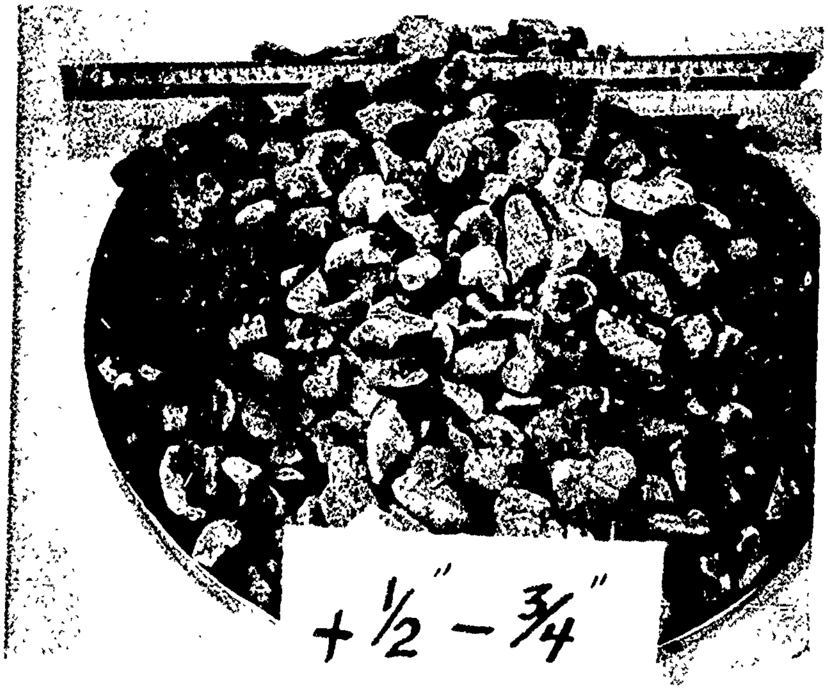


a. 3/8"-#4 fraction



b. 1/2"-3/8" fraction

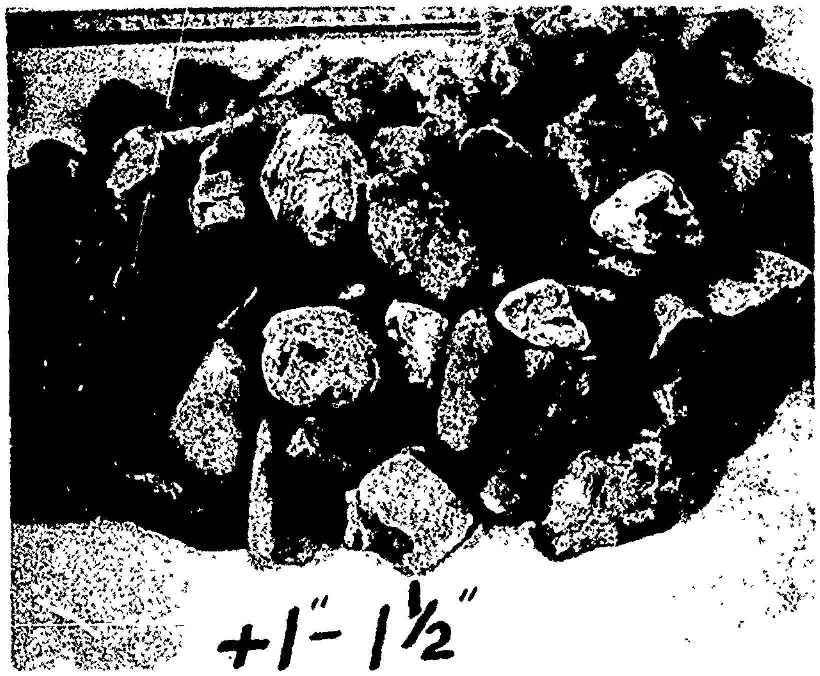
Fig. 4. DeGray material, 3/8"-#4 and 1/2"-3/8" fractions



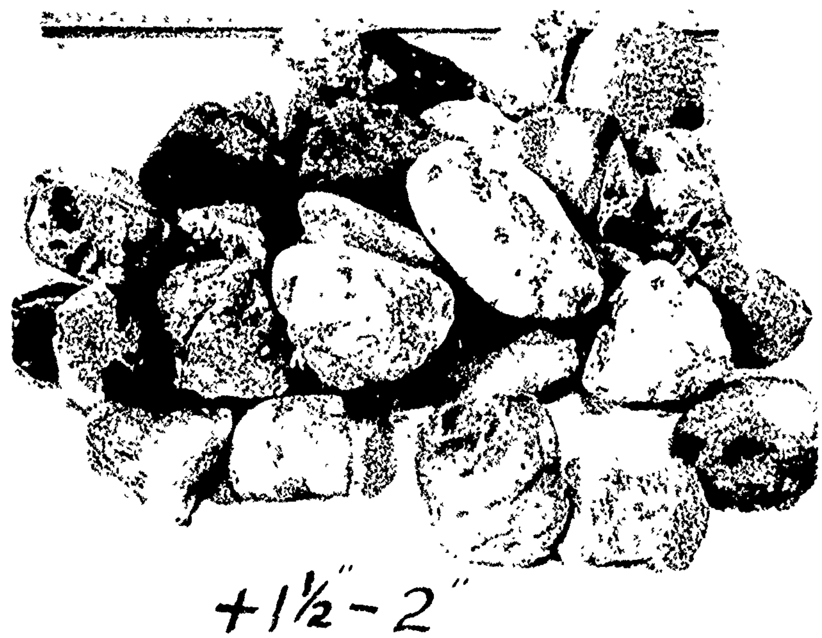
a. 3/4"-1/2" fraction

b. 1"-3/4" fraction

Fig. 5. DeGray material, 3/4"-1/2" and 1"-3/4" fractions



a. 1-1/2"-1" fraction



b. 2"-1-1/2" fraction

Fig. 6. DeGray material, 1-1/2"-1" and 2"-1-1/2" fractions

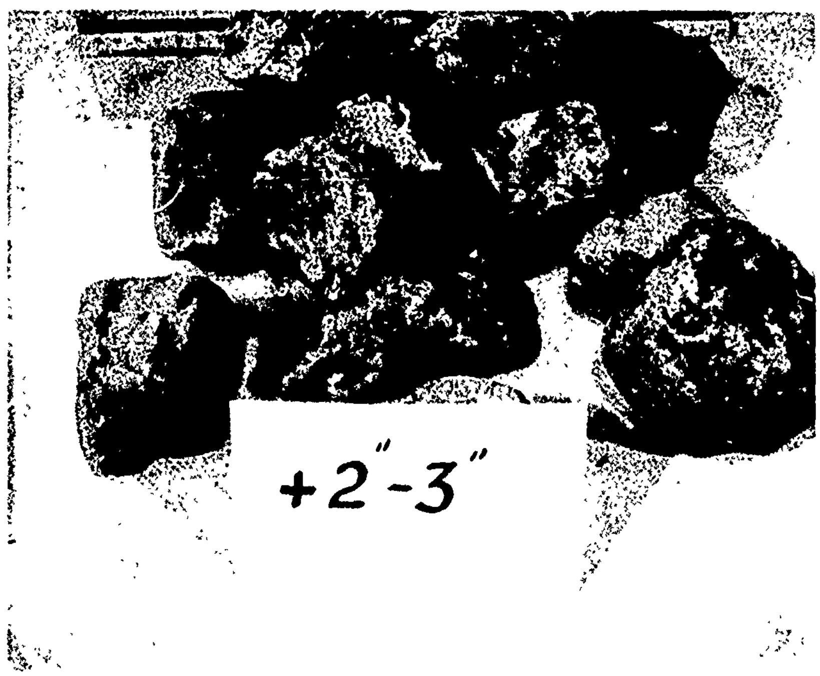


Fig. 7. DeGray material, 3"-2" fraction

series of tests was conducted with the 6-in.-diam mold using material processed in the pugmill. Individual batches weighing 9.25 lb were mixed in the mixer and then placed in airtight containers. Preparation of the material using the pugmill consisted of processing individual 50-lb batches until sufficient material for an entire sample was prepared and then passing all the moistened soil through the pugmill prior to storage in airtight containers. The moistened soil resulting from both methods of preparation was allowed to cure in airtight containers for at least 16 hr prior to being compacted.

9. Batches for test specimens of the DeGray material were prepared by thoroughly mixing a predetermined amount of air-dry minus No. 4 material with a measured quantity of water in a 6-cu-ft mortar box. The moistened minus No. 4 material was then stored in airtight containers and allowed to cure for a period of at least 16 hr. The plus No. 4 material required for each batch was prepared by combining the air-dry portion (by weight) of material required for each sieve and then storing the resulting material in containers filled with water. Immediately prior to compaction, the cured minus No. 4 fraction was mixed with the saturated surface-dry aggregate. Except in tests using the 4- and 6-in. molds, each layer of the DeGray material was batched separately to prevent any variations in grading between layers.

10. Table 1 lists pertinent data of the molds and rammer sizes used in the tests. All specimens were compacted in three layers, using compactive efforts approximately equal to the standard effort (12,300 ft-lb/ft^3) by adjusting the number of blows. To isolate the effects of scalping and replacing from the effects due to mold size, the moisture-density relationships of the scalped and replaced

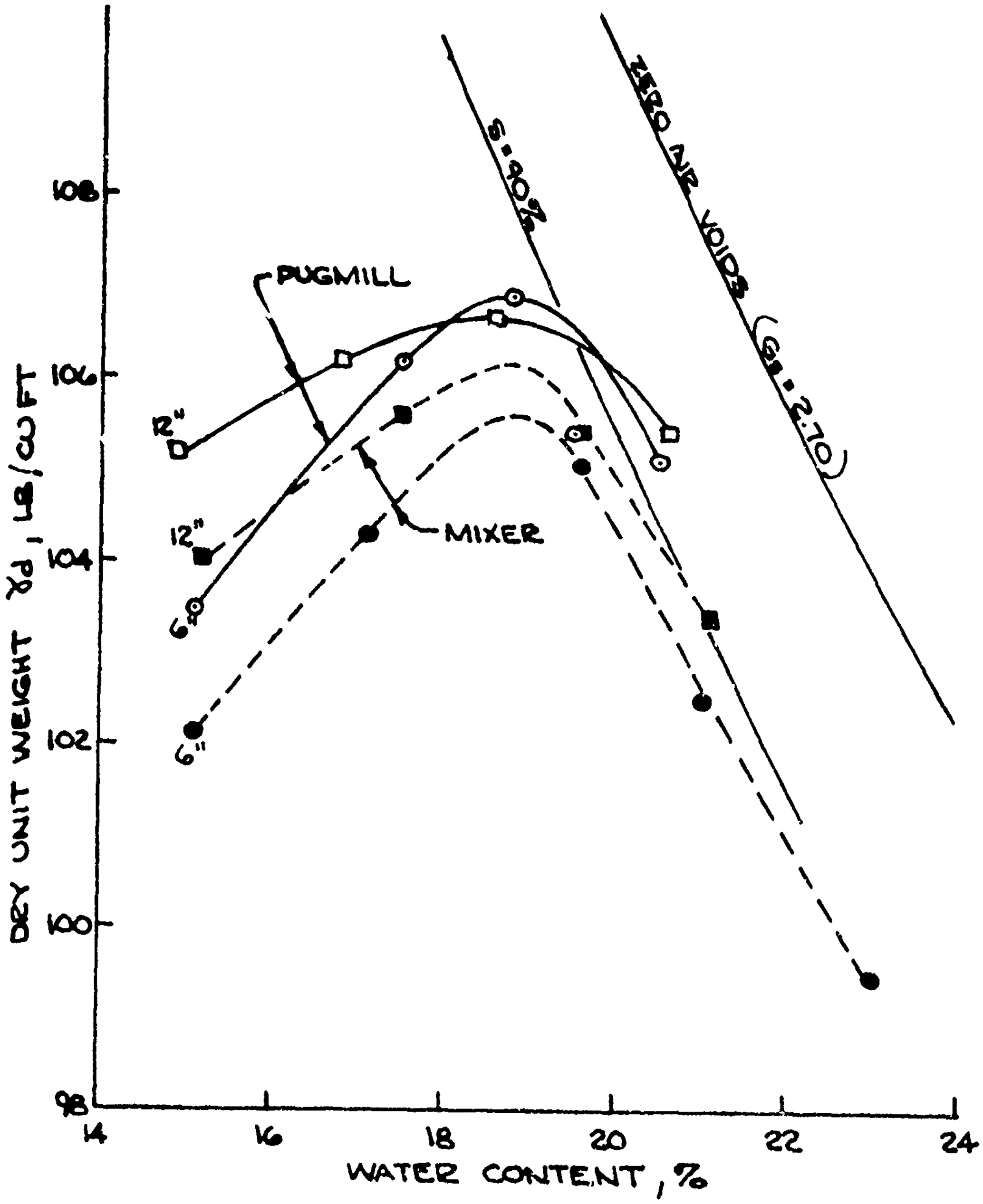
material used in the 6-in.-diam mold were also determined using the 18-in.-diam mold.

11. Compacted specimens containing gravel could not be trimmed flush with the top of the mold without significantly disturbing the specimens. Hence, the volumes of these specimens were determined by measuring the distance from the top of the mold collar to the top of the specimen and using this distance to compute the volume of the mold collar not occupied by the specimen. This volume was then subtracted from the volume of the mold plus collar to determine the specimen volume. Finally, the total specimen was oven-dried for water content determinations.

Test Results

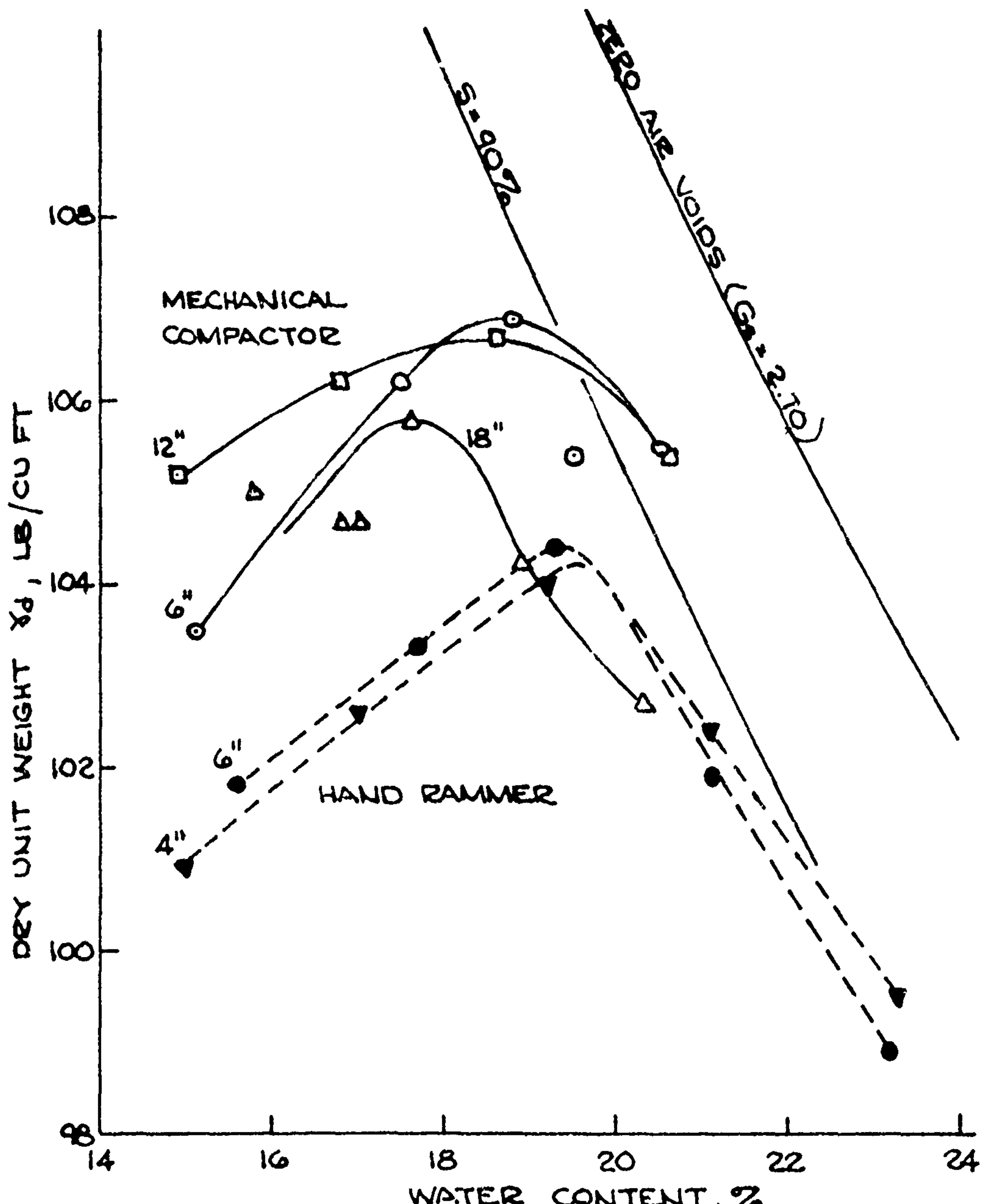
CL material

12. Compaction curves and a tabulation of maximum dry unit weights and optimum water contents for the CL material batched in the mixer and pugmill and compacted in the 6- and 12-in.-diam molds of the Howard compactor are given in fig. 8. The curves indicate that maximum dry unit weights of material processed in the pugmill were only 1.3 and 0.5 pcf higher for the 6- and 12-in.-diam molds, respectively, than those for material prepared in the mixer, while optimum water contents were about the same. The compaction curves presented in fig. 9 indicate that the maximum dry unit weight and optimum moisture content varied slightly for specimens of pugmill-prepared material compacted in 6-, 12-, and 18-in.-diam molds using the Howard compactor, and that there was no significant difference in results for the 4- and 6-in.-diam molds using the hand-held, sliding-weight rammer. The ranges of maximum dry unit



	PROCESSED USING			
	MIXER		PUGMILL	
SYMBOL	●	■	○	□
MOLD DIAM, IN.	6	12	6	12
OPT ω, %	18.8	18.7	18.7	18.6
MAX γd, PCF	105.6	106.2	106.9	106.7

Fig. 8. Compaction curves, Vicksburg silty clay compacted with Howard Compactor



	HAND-HELD RAMMER MIXER PROCESSED		HOWARD COMPACTOR PUGMILL PROCESSED		
SYMBOL	▼	●	○	□	△
MOLD DIAM, IN.	4	6	6	12	18
OPT. ω, %	19.6	19.5	18.7	18.6	17.6
MAX. γd, PCF	104.2	104.4	106.9	106.7	105.8

Fig. 9. Compaction curves, Vicksburg silty clay compacted by hand-held rammer and mechanical compactor

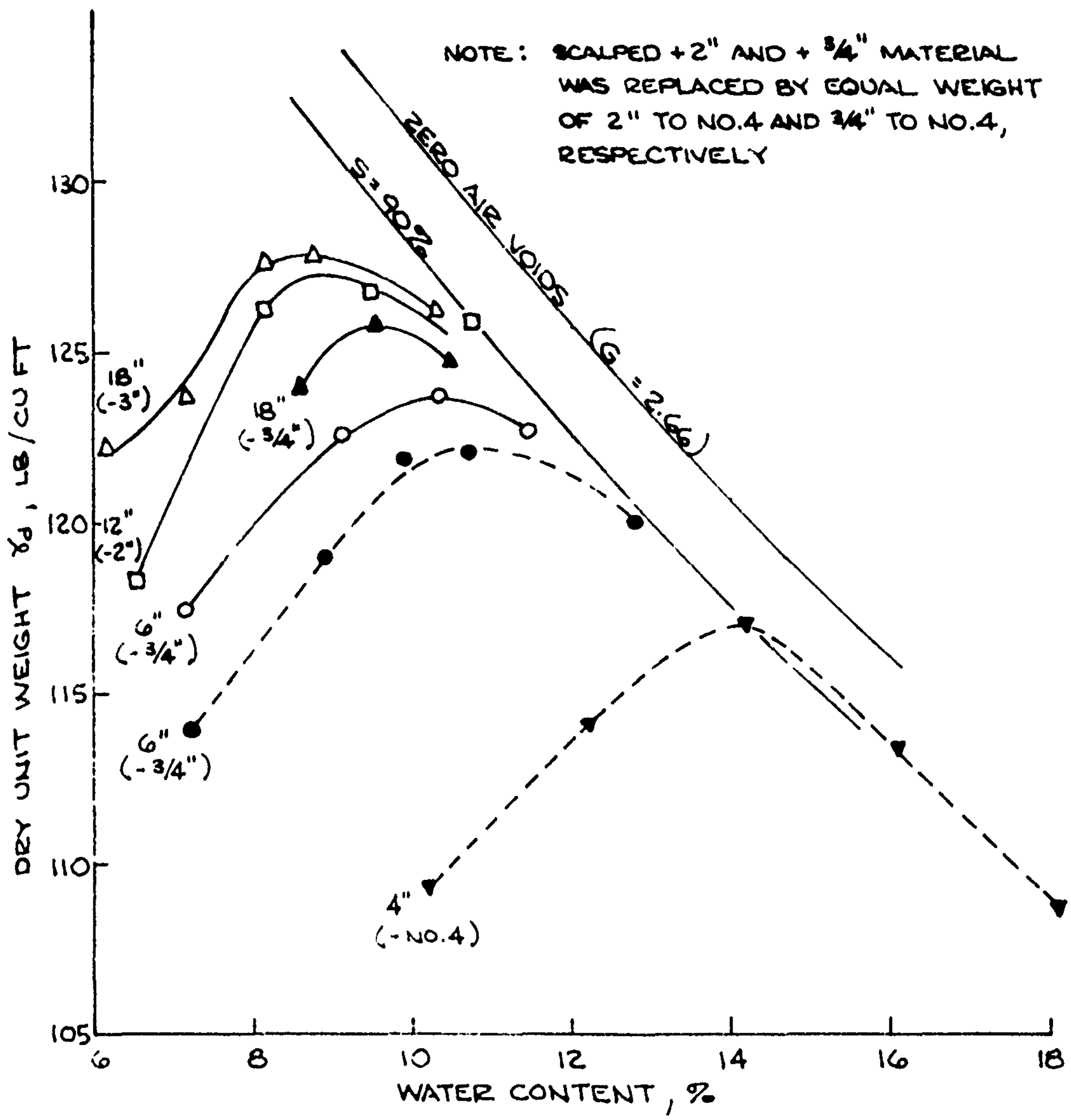
weights and optimum water contents for both methods of compaction, regardless of batching procedure or mold size, are tabulated below:

Compaction Method	Maximum Dry Unit Weight, pcf	Optimum Water Content, %
Hand-held rammer	104.2-104.4	19.5-19.6
Howard compactor	105.6-106.9	17.6-18.8

Differences in results for the tests performed with the various molds using the mechanical compactor fall within ranges comparable to those determined by Ziegler[1] and Cunny and Strohm,[4] who concluded that the size of the mold does not significantly affect the test results. It should be remembered, however, that results may also be affected by the increased weights and diameters of the rammers generally used for 12- and 18-in.-diam molds as well as the increased layer heights, and that, in this investigation, the hammer sizes and layer heights used were such that their effect on the compaction characteristics of the CL material was not significant. As can be seen by a comparison of the results for the tests on mixer-processed CL material using 6-in.-diam molds (figs. 8 and 9), the mechanical compactor gave values of optimum water content and maximum dry unit weights which were 0.7 percent lower and 1.2 pcf greater, respectively, than the corresponding values determined with the hand-held rammer. The maximum spread in test results was 2.0 percent for optimum water content (4-in. vs 18-in. mold) and 2.7 pcf in density (4-in. vs 6-in. mold).

DeGray material

13. Figure 10 shows compaction curves for each of the gradations of the DeGray material shown in fig. 3. The following tabulation, based on the data in fig. 10, shows the effects of mold size and



	HAND RAMMER		HOWARD COMPACTOR			
SYMBOL	▼	●	○	□	△	▲
MOLD DIAM., IN.	4	6	6	12	18	18
MAX. PART. SIZE	NO.4	3/4"	3/4"	2"	3"	3/4"
OPT ω, %	14.2	10.8	10.3	8.9	8.7	9.5
MAX γd, PCF	117.0	122.4	123.6	127.3	127.9	125.8

Fig. 10. Compaction curves, DeGray clayey sandy gravel compacted by hand-held rammer and mechanical compactor

gradation on maximum dry density and optimum water content:

Identification	Maximum Particle Size in.	Mold Diameter in.	Optimum Water Content %	Maximum Dry Unit Wt pcf
a	3	18	8.7	127.9
b	2	12	8.9	127.3
c	3/4	6	10.3	123.6
d	3/4	18	9.5	125.8
e Effect of maximum particle size and mold and rammer size (a − c)			−1.6	+4.3
f Effect of maximum particle size (a − d)			−0.8	+2.1
g Effect of mold and rammer size (e − f)			−0.8	+2.2

These results show that the scalping and replacement procedure resulted in lower dry unit weights and increased optimum water contents as smaller maximum particle sizes and corresponding smaller molds were used with the Howard compactor.

14. Shockley[2] reported the following theoretical equation for determining the dry density of earth-rock mixtures:

$$\gamma_d = \frac{\gamma_f G_c \gamma_w}{\gamma_f P_c + G_c \gamma_w P_f}$$

where

γ_d = calculated dry density of total sample

γ_f = dry unit weight of finer fraction

G_c = bulk specific gravity of coarser fraction (based on ovendry weights). Same as G_m .

γ_w = unit weight of water

P_c = percent of coarser material by weight in the total sample

P_f = percent of finer material by weight in the total sample

This equation is based on the assumption that all of the void spaces in an earth-rock mass are associated with the fine fraction and are not influenced by the presence of the gravel particles. Generally, γ_f is considered to be the density of minus No. 4 material. However, its value can be based upon other sizes. For example, calculations can be made for plus 3/4-in. material if the density of the minus 3/4-in. material is known. In this case, P_f and P_c are the percentages of material finer and coarser than 3/4 in., respectively. The results presented in fig. 11 show the relationship of the theoretical dry unit weight for the DeGray material with various percentages of gravel. Also shown are experimental values for minus 3-in. material compacted in the 18-in.-diam mold. As can be seen, the theoretical value is approximately 5 lb per cu ft greater than the experimentally determined value for the 3-in. maximum particle size sample when γ_f is considered to be the density of the minus No. 4 material. A slightly better theoretical estimate is obtained when γ_f is considered to be the density of the minus 3/4-in. material; however, the difference (4.3 pcf) is still considerable. These test results confirm the findings of Ziegler[1] in that the maximum dry density determined on material with 3-in. maximum size is lower than the theoretically computed values when the gravel content is above a lower limiting value (usually 10 to 25 percent, depending on the material). The deviations between the experimental and theoretical densities are attributed to the interference of the coarse particles, which prevents complete compaction of the finer sizes between these larger particles. To date, no attempt has been made to correlate the test results with other theoretical expressions that take into account the interference of the coarse particles since these

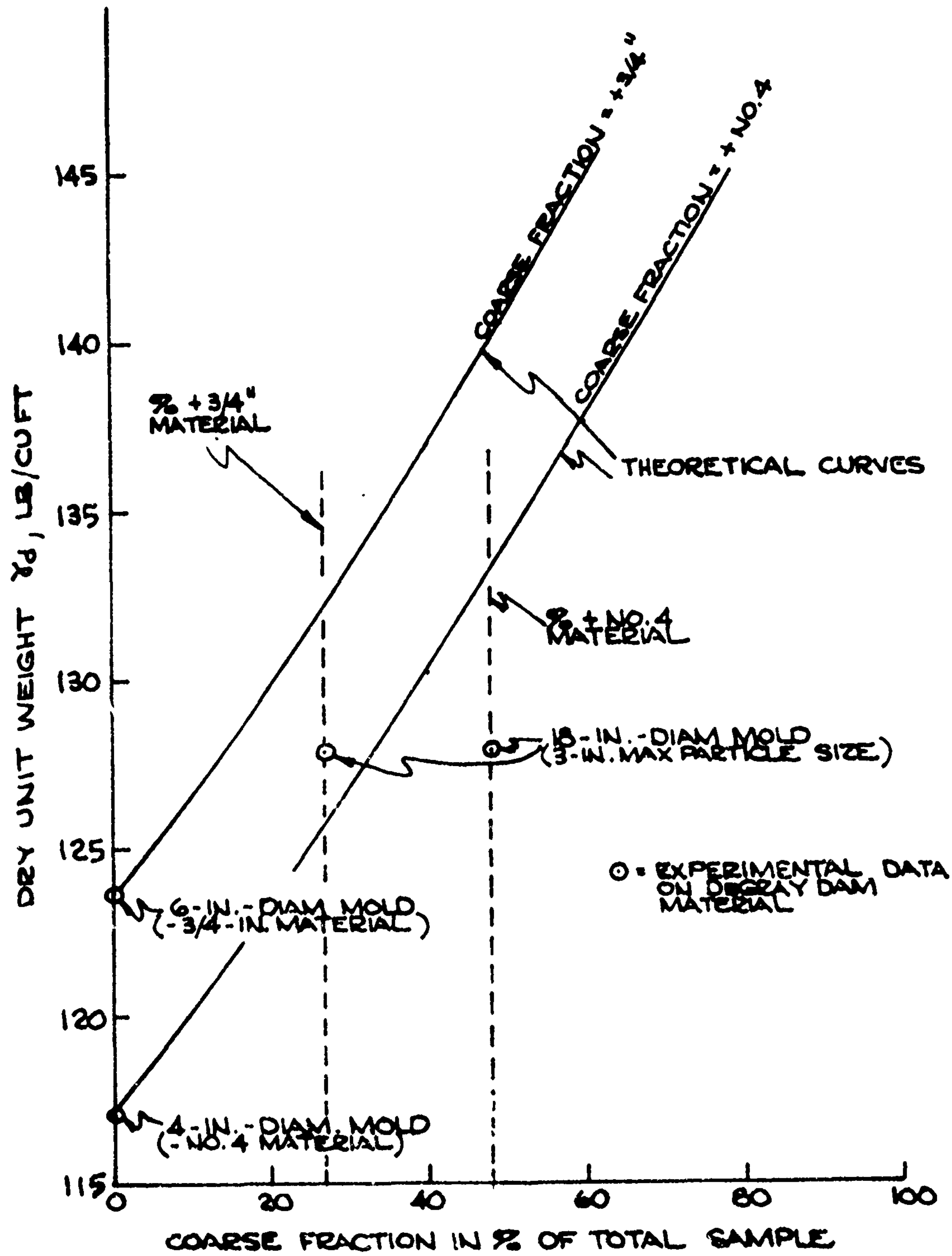


Fig. 11. Theoretical and experimental densities of clayey sandy gravel (GC) DeGray meterial

expressions require tests performed on samples containing various percentages of gravel. Such correlations will be made after future testing to determine the effect of gravel content on the compaction characteristics is completed.

Conclusions

15. The results of this preliminary program of compaction tests performed using the Howard mechanical compactor and standard compactive effort appear to indicate that:

a. Mold diameters can be varied from 6 to 18 in. with only slight effects on the maximum dry unit weight and optimum water content of a fine-grained CL soil. In the case of tests using 6- to 18-in.-diam molds performed on Vicksburg silty clay (CL), maximum dry unit weights ranged from 105.8 to 106.9 lb per cu ft and optimum water contents ranged from 17.6 to 18.8. The effects of pugmill versus mixer processing of CL material appear to be relatively insignificant.

b. Significant differences were found in results of tests on a clayey sandy gravel with a maximum particle size of 3 in. in an 18-in.-diam mold and tests in a 6-in.-diam mold using the minus 3/4-in. material with replacement of plus 3/4-in. material. The maximum dry unit weight was decreased from 127.9 lb per cu ft on the total sample to 123.6 lb per cu ft, and the optimum water content was increased from 8.7 to 10.3 percent.

The conclusions above refer only to mechanical compaction and may be valid only for the sizes of compaction equipment (rammers, etc.) furnished with the Howard compactor. Tests on both the CL and GC materials indicate that the mechanical compactor consistently gave higher maximum dry unit weights and somewhat lower optimum water contents than sliding-weight rammers, indicating that compactive effort of the mechanical rammer should be reduced to obtain a better agreement.

16. Further testing utilizing samples containing various percentages of gravel is needed to determine fully the effects of scalping and replacing coarse material. A testing program to investigate effects due to the percentage of gravel in a mixture, the gradation and particle geometry of the gravel, and the plasticity of the fines is being planned.

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Table 1

Compaction Tests Using Hand-Held Sliding Weight Rammer and Howard Mechanical Compactor

Mold Diam in.	Compactive Effort ft-lb/ft^3	Rammer* Wt lb	Rammer* Diam of Circular Face in.	Rammer* Drop in.	No. of Layers	Blows per Layer	Complete Coverages of Mold Area	Blows per Coverage: Along Circumference of Mold	Blows per Coverage: At Center of Specimen
Vicksburg Silty Clay (CL)									
4	12,300	5.5	2	12	3	25	-	-	-
6	12,420	5.5	2	12	3	56	2	24	4
12	12,262	24.7	6	24	3	65	4	16**	-
18	12,299	24.7	6	24	3	220	7	24 †	6††
DeGray Dam Clayey Sandy Gravel (GC)									
4	12,300	5.5	2	12	3	25	-	-	-
6	12,420	5.5	2	12	3	56	2	24	4
12	12,262	24.7	6	24	3	65	4	16**	-
18	12,299	24.7	6	24	3	220	7	24 †	6††

* Compaction equipment used:
hand compaction: 4-in. mold
hand and mechanical compaction: 6-in. mold
mechanical compaction: 12- and 18-in. molds

** Plus 1 on last coverage

† Plus 6 on last coverage

†† Plus 4 on last coverage

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Appendix A

Scalping and Replacement Procedure

The Corps of Engineers scalping and replacement procedure outlined in reference 7 follows:

a. Spread the material to be tested in flat pans and air-dry the entire sample. Other means, such as ovens and heat lamps, may be used to accelerate drying if the maximum drying temperature is 60 C.

b. Reduce all aggregates, or lumps formed during drying, of fine-grained material to particles finer than the No. 4 sieve. With a wire brush or other means, remove all fine-grained material that may be clinging to rock sizes, taking care not to lose the fine-grained material.

c. Separate all the material using a set of sieves ranging from the largest particle size in the sample to the No. 4 sieve. The total sample must be processed to determine the as-received gradation.

d. Place the material retained on each sieve and that passing the No. 4 sieve in separate containers, weigh the contents of each, and compute the percentage of the total sample retained on each sieve as follows:

$$\% \text{ retained} = \frac{\text{dry weight of material retained on sieve}}{\text{dry weight of total sample}} \times 100$$

e. If 10 percent or less of a field sample is retained on the 2-in. sieve, the particles larger than this size should be discarded and replacement is not necessary.

f. If more than 10 percent of a field sample is retained on the 2-in. sieve, it will be necessary to remove the plus 2-in. sizes and replace them with an equal weight of material between the 2-in. and No. 4 sieve sizes. The gradation of the replacement material must be the same relative gradation as that of the total sample between the 2-in. and the No. 4 sieve sizes. The percent passing the No. 4 sieve remains constant and is equal to the percent passing the No. 4 sieve for the total as-received sample. For each sieve between the 2-in. and the No. 4 sizes, the percent required to replace the plus

2-in. sizes is computed as follows:

$$\text{Replacement \%} = \text{total \% of +2-in. sizes X} \frac{\text{\% retained on one sieve*}}{\text{total \% between 2-in. and No. 4 sieve}}$$

For each sieve, add the "Replacement %" to the "% Retained" on that sieve initially. This gives the percent by weight of a test specimen required for each sieve size in order to reconstitute a specimen with the +2-in. sizes replaced with sizes ranging from the 2-in. to the No. 4 sizes.

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* Any sieve between 2-in. and No. 4 sieve sizes.